

PATENT ABSTRACTS OF JAPAN

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(71)Applicant : NEC TOKIN CORP

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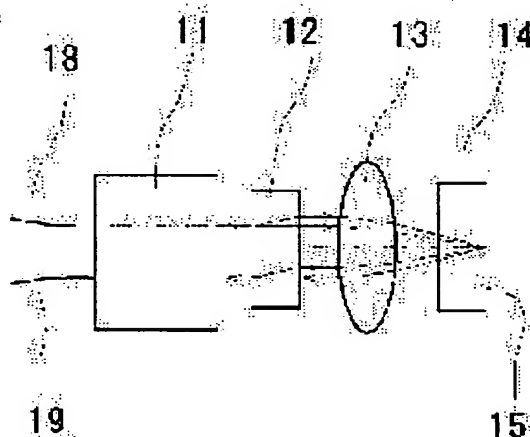
(72)Inventor : SASAKI NOBUHIRO
KONDO MITSUKAZU

(54) OPTICAL ATTENUATOR

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a low cost optical attenuator to reduce the number of components.

SOLUTION: The optical attenuator comprises a two core optical fiber, a walk-off crystal, a lens and a variable Faraday rotor having a totally reflecting film on one optical face sequentially arranged in the direction of an optical path. The variable Faraday rotor having the totally reflecting film on one optical face can be replaced with the variable Faraday rotor and a totally reflecting mirror. The variable Faraday rotor may be provided with a Faraday rotating material, an electromagnet and a permanent magnet.



LEGAL STATUS

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CLAIMS

[Claim(s)]

[Claim 1] The optical attenuator characterized by arranging the adjustable Faraday rotator which has the total reflection film in 2 heart optical fiber, a walk-off crystal, a lens, and one side of an optical surface at this order, and changing in the direction of an optical path.

[Claim 2] The optical attenuator characterized by 2 heart optical fiber, the walk-off crystal, the lens, adjustable Faraday rotator, and arranging a total reflection mirror at this order, and changing in the direction of an optical path.

[Claim 3] Said adjustable Faraday rotator is an optical attenuator given in either of claims 1 or 2 characterized by having a Faraday-rotation ingredient, an electromagnet, and a permanent magnet, and being constituted.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention] This invention relates to the optical attenuator which decreases and adjusts optical reinforcement in an optical transmission system etc., and relates to the optical attenuator of good transformation which uses for wavelength-multiplex-optical-telecommunications equipment, and is especially equipped with suitable Faraday rotator.

[0002]

[Description of the Prior Art] A faraday's rotation angle is controlled by control of a current, and since the optical attenuator which decreases light does not have a part for mechanical moving part, it operates as a reliable optical attenuator. Since especially the optical attenuator using the Faraday rotator which the include angle between the magnetization direction and the direction of light transmission is changed, and controls a faraday's rotation angle, with magnetization of a Faraday-rotation crystal saturated does not cause light scattering by change of a magnetic domain, it operates as an attenuator with little a polarization dependency and superfluous loss.

[0003] The configuration of the general optical attenuator used for drawing 5 from the former is shown. The light which carried out outgoing radiation of the optical fiber 51a is changed into the parallel flux of light by lens 52a, and carries out incidence to wedge shape birefringence crystal 53a. When passing this crystal, the amount of [a part for usual state Mitsunari of light and] abnormality Mitsunari receives the refraction according to each refractive index. Next, by adjustable Faraday rotator 54, the light of each component penetrates wedge shape birefringence crystal 53b, after receiving about 0-90-degree rotatory polarization, and it is changed into the convergence flux of light by lens 52b, and a part of light combines it with optical fiber 51b.

[0004] Here, the sense of the wedge in the wedge shape birefringence crystals 53a and 53b is reverse sense, and the direction of a c-axis (optical axis) lies at right angles mostly. Therefore, when the faraday's rotation angle by adjustable Faraday rotator 54 is about 90 degrees, similarly the light which passed wedge shape birefringence crystal 53a as Tsunemitsu passes wedge shape birefringence crystal 53b as Tsunemitsu. Consequently, change of the travelling direction of light received as the wedge shape birefringence crystals 53a and 53b is negated mutually, and a part for all usual state Mitsunari is combined with optical fiber 51b. Moreover, the situation is the same also to the light which passes wedge shape birefringence crystal 53a as an abnormality light.

[0005] When a faraday's rotation angle is 0 degree, in order that [two] the light which passes one side of the wedge shape birefringence crystals 53a and 53b as Tsunemitsu may pass through another side as an abnormality light to it, change of the travelling direction when passing the rust form birefringence crystal which goes away is not negated mutually. Consequently, light is not combined with optical fiber 51b.

[0006] Therefore, when a faraday's rotation angle is 90 degrees, the magnitude of attenuation is zero, and the magnitude of attenuation increases as a faraday's rotation angle approaches 0 degree.

[0007]

[Problem(s) to be Solved by the Invention] In the optical attenuator explained as a conventional example, the rutile form birefringence crystal which goes away two sheets is used. Moreover, it is necessary to make polarization distribution into zero in many applications of an optical attenuator, and, then, the polarization distribution compensating plate which is the birefringence crystal of one more sheet is needed.

[0008] Generally the manufacture cost of a birefringence crystal component or a lens cannot be reduced easily. So, use of many birefringence crystal components or a lens pulls up the manufacture cost of an optical attenuator.

[0009] Then, this invention decreases components mark and makes it a technical problem to offer the optical attenuator of low cost.

[0010]

[Means for Solving the Problem] In order to attain the above-mentioned purpose, in the optical attenuator of this invention, components mark are decreased by making a walk-off crystal, a lens, and adjustable Faraday rotator penetrate light both ways.

[0011] That is, the adjustable Faraday rotator which has the total reflection film in 2 heart optical fiber, a walk-off crystal, a lens, and one side of an optical surface is arranged in the direction of an optical path at this order, and the optical attenuator of this invention is constituted.

[0012] Moreover, the optical attenuator of this invention can also equip with and constitute a total reflection mirror with 2 heart optical fiber, a walk-off crystal, a lens, and adjustable Faraday rotator.

[0013] Furthermore, said adjustable Faraday rotator is equipped with a Faraday-rotation ingredient, an electromagnet, and a permanent magnet, and may be constituted.

[0014]

[Embodiment of the Invention] Next, the gestalt of operation of this invention is explained based on drawing 1 - drawing 4.

[0015] (Gestalt 1 of operation) Drawing 1 is the mimetic diagram showing the optical configuration of the optical attenuator by the gestalt 1 of operation of this invention. 11 is the optical fiber of the 2 hearts and unifies the optical fiber 18 of an input, and the optical fiber 19 of an output. 12 is a walk-off crystal, 13 is a convex lens, 14 is adjustable Faraday rotator, and the total reflection film 15 is formed in one side of this optical surface.

[0016] Here, adjustable Faraday rotator 14 used is explained based on drawing 3. In drawing 3, 32 is Bi permutation rare earth iron garnet crystal, 31a and 31b are York of an electromagnet, and 33 is a permanent magnet. It progresses in accordance with an optical path 34, and is reflected by the total reflection film formed in the near optical surface of a permanent magnet 33, and light goes back an optical path 34.

[0017] Moreover, the dimension of Bi permutation rare earth iron garnet crystal 32 is 0.8x0.8x0.4mm, the fixed field system of the direction of an optical path 34 is impressed with a permanent magnet 33, and the adjustable field which intersects perpendicularly with an optical path 34 by York 31a and 31b of an electromagnet is impressed.

[0018] By controlling the current of this electromagnet, the direction of the saturation magnetization of Bi permutation rare earth iron garnet crystal 32 is controlled, and an about 0-90-degree adjustable faraday's rotation angle is acquired both ways.

[0019] The parallel plate of a rutile single crystal can be used for the walk-off crystal 12 of drawing 1, and it is easy to use the thing of the thickness which is about 0.75mm for it. Moreover, it is easy to use a thing with a focal distance of about 2mm as a convex lens 13.

[0020] Advance of the light in the optical attenuator by the gestalt of this operation is explained based on drawing 4. First, the case where the joint effectiveness from the input side of 2 heart optical fiber to an output side is about 100% is explained based on drawing 4 (a). Carrying out incidence of the light which carried out outgoing radiation from the fiber of 2 heart optical fiber top to the walk-off crystal 12, by whether you are Tsunemitsu or it is abnormality light, it separates into the optical path of 16a and 17a, and after outgoing radiation makes a travelling direction parallel, and progresses, respectively. Then, two light was changed into the parallel flux of light by the convex lens, and carried out incidence to adjustable Faraday rotator 14 with it, it

was reflected by the total reflection film 15, and when carrying out outgoing radiation, they has received 90-degree Faraday rotation. Next, although two light is changed into convergence light by the convex lens 13, after outgoing radiation, the travelling direction of those light becomes parallel again, advances in accordance with the optical path of 16b and 17b, and carries out incidence to the walk-off crystal 12.

[0021] At this time, the light which was Tsunemitsu passes the walk-off crystal 12 as an abnormality light on an outward trip to because of that of the 90-degree plane-of-polarization rotation received by adjustable Faraday rotator. Moreover, on an outward trip, the light which was abnormality light passes a return trip as Tsunemitsu. Consequently, outgoing radiation of the two light is carried out to the same optical path, and they is combined with the optical fiber of 2 heart optical fiber bottom.

[0022] Next, the case where there is almost no association to an output side from the input side of 2 heart optical fiber is explained based on drawing 4 (b). In this case, by the field of an electromagnet, the direction of magnetization of a Faraday-rotation ingredient and the travelling direction of light become almost perpendicular, and the faraday's rotation angle has become zero mostly. However, in a return trip, again, the optical path of two light is in agreement with drawing 4 (a) until it carries out incidence to the walk-off crystal 12.

[0023] However, in the walk-off crystal 12, the light which the light which was abnormality light on the outward trip was abnormality light also in the return trip, and was Tsunemitsu on the outward trip is Tsunemitsu also in a return trip, and when carrying out outgoing radiation, two light expands separation width of face further, and it carries out incidence to the point which is separated from the core of a lower optical fiber. That is, not almost all light is combined with the optical fiber of an output side.

[0024] So, in order to obtain the predetermined magnitude of attenuation, the current added to an electromagnet is controlled, the direction of the synthetic field of an electromagnet and a permanent magnet is controlled, by this, the include angle between the direction of the saturation magnetization of a Faraday-rotation ingredient and the travelling direction of light is adjusted, and a faraday's rotation angle is adjusted. Therefore, when the current of an electromagnet is zero, the magnitude of attenuation is zero mostly, and the magnitude of attenuation increases it while increasing the current of an electromagnet.

[0025] By the way, what is necessary is to constitute a collimator from a 2 heart optical fiber, a walk-off crystal, and a convex lens, and just to adjust the distance of a convex lens and the total reflection film of adjustable Faraday rotator, and the include angle of the medial axis of a convex lens, and the total reflection film of adjustable Faraday rotator to make after that about assembly.

[0026] (Gestalt 2 of operation) Drawing 2 is the mimetic diagram showing the optical configuration of the optical attenuator by the gestalt 2 of operation of this invention. 21 is the optical fiber of the 2 hearts and, for 22, as for a convex lens and 24, a walk-off crystal and 23 are [adjustable Faraday rotator and 25] total reflection mirrors.

[0027] Here, adjustable Faraday rotator 24 can be constituted by arranging the total reflection mirror 25 between Bi permutation rare earth iron garnet crystal 32 shown in drawing 3 , and a permanent magnet 33.

[0028] About advance actuation of light, it is the same as that of the gestalt 1 of operation. Since it is only the point that adjustable Faraday rotator 24 and the total reflection mirror 25 were separated, that the degree of freedom of optical-path adjustment increases only differ.

[0029] What is necessary is just to use a walk-off crystal, a lens, and one Bi permutation rare earth iron garnet crystal at a time in the two above-mentioned operation gestalten, respectively. Moreover, Bi permutation rare earth iron garnet crystal is good by the thickness of the one half of the conventional example.

[0030] Moreover, in the optical attenuator of this invention, since the optical fiber of I/O is pulled out by one side, it can make the management tooth space of an optical fiber small.

[0031] Furthermore, in the optical attenuator of this invention, in two optical paths separated according to polarization, since the optical path length is equal, a polarization distribution compensating plate is not needed.

[0032] Therefore, low cost-ization by reduction of components mark is attained in the optical attenuator of this invention. Moreover, since the approach of assembly is as the gestalt 1 of operation having explained, there are few the man days.

[0033]

[Effect of the Invention] As explained above, according to this invention, there are few components mark, it is small, and it becomes possible to offer the optical attenuator of low cost.

[Translation done.]

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TECHNICAL FIELD

[Field of the Invention] This invention relates to the optical attenuator which decreases and adjusts optical reinforcement in an optical transmission system etc., and relates to the optical attenuator of good transformation which uses for wavelength-multiplex-optical-telecommunications equipment, and is especially equipped with suitable Faraday rotator.

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PRIOR ART

[Description of the Prior Art] A faraday's rotation angle is controlled by control of a current, and since the optical attenuator which decreases light does not have a part for mechanical moving part, it operates as a reliable optical attenuator. Since especially the optical attenuator using the Faraday rotator which include angle between the magnetization direction and the direction of light transmission is changed, and controls a faraday's rotation angle, with magnetization of a Faraday-rotation crystal saturated does not cause light scattering by change of a magnetic domain, it operates as an attenuator with little a polarization dependency and superfluous loss.

[0003] The configuration of the general optical attenuator used for drawing 5 from the former is shown. The light which carried out outgoing radiation of the optical fiber 51a is changed into the parallel flux of light by lens 52a, and carries out incidence to wedge shape birefringence crystal 53a. When passing this crystal, the amount of [a part for usual state Mitsunari of light and] abnormality Mitsunari receives the refraction according to each refractive index. Next, by adjustable Faraday rotator 54, the light of each component penetrates wedge shape birefringence crystal 53b, after receiving about 0-90-degree rotatory polarization, and it is changed into the convergence flux of light by lens 52b, and a part of light combines it with optical fiber 51b.

[0004] Here, the sense of the wedge in the wedge shape birefringence crystals 53a and 53b is reverse sense, and the direction of a c-axis (optical axis) lies at right angles mostly. Therefore, when the faraday's rotation angle by adjustable Faraday rotator 54 is about 90 degrees, similarly the light which passed wedge shape birefringence crystal 53a as Tsunemitsu passes wedge shape birefringence crystal 53b as Tsunemitsu. Consequently, change of the travelling direction of light received as the wedge shape birefringence crystals 53a and 53b is negated mutually, and a part for all usual state Mitsunari is combined with optical fiber 51b. Moreover, the situation is the same also to the light which passes wedge shape birefringence crystal 53a as an abnormality light.

[0005] When a faraday's rotation angle is 0 degree, in order that [two] the light which passes one side of the wedge shape birefringence crystals 53a and 53b as Tsunemitsu may pass through another side as an abnormality light to it, change of the travelling direction when passing the rust form birefringence crystal which goes away is not negated mutually. Consequently, light is not combined with optical fiber 51b.

[0006] Therefore, when a faraday's rotation angle is 90 degrees, the magnitude of attenuation is zero, and the magnitude of attenuation increases as a faraday's rotation angle approaches 0 degree.

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EFFECT OF THE INVENTION

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TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] In the optical attenuator explained as a conventional example, the rust form birefringence crystal which goes away two sheets is used. Moreover, it is necessary to make polarization distribution into zero in many applications of an optical attenuator, and, then, the polarization distribution compensating plate which is the birefringence crystal of one more sheet is needed.

[0008] Generally the manufacture cost of a birefringence crystal component or a lens cannot be reduced easily. So, use of many birefringence crystal components or a lens pulls up the manufacture cost of an optical attenuator.

[0009] Then, this invention decreases components mark and makes it a technical problem to offer the optical attenuator of low cost.

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MEANS

[Means for Solving the Problem] In order to attain the above-mentioned purpose, in the optical attenuator of this invention, components mark are decreased by making a walk-off crystal, a lens, and adjustable Faraday rotator penetrate light both ways.

[0011] That is, the adjustable Faraday rotator which has the total reflection film in 2 heart optical fiber, a walk-off crystal, a lens, and one side of an optical surface is arranged in the direction of an optical path at this order, and the optical attenuator of this invention is constituted.

[0012] Moreover, the optical attenuator of this invention can also equip with and constitute a total reflection mirror with 2 heart optical fiber, a walk-off crystal, a lens, and adjustable Faraday rotator.

[0013] Furthermore, said adjustable Faraday rotator is equipped with a Faraday-rotation ingredient, an electromagnet, and a permanent magnet, and may be constituted.

[0014]

[Embodiment of the Invention] Next, the gestalt of operation of this invention is explained based on drawing 1 - drawing 4.

[0015] (Gestalt 1 of operation) Drawing 1 is the mimetic diagram showing the optical configuration of the optical attenuator by the gestalt 1 of operation of this invention. 11 is the optical fiber of the 2 hearts and unifies the optical fiber 18 of an input, and the optical fiber 19 of an output. 12 is a walk-off crystal, 13 is a convex lens, 14 is adjustable Faraday rotator, and the total reflection film 15 is formed in one side of this optical surface.

[0016] Here, adjustable Faraday rotator 14 used is explained based on drawing 3. In drawing 3, 32 is Bi permutation rare earth iron garnet crystal, 31a and 31b are York of an electromagnet, and 33 is a permanent magnet. It progresses in accordance with an optical path 34, and is reflected by the total reflection film formed in the near optical surface of a permanent magnet 33, and light goes back an optical path 34.

[0017] Moreover, the dimension of Bi permutation rare earth iron garnet crystal 32 is 0.8x0.8x0.4mm, the fixed field system of the direction of an optical path 34 is impressed with a permanent magnet 33, and the adjustable field which intersects perpendicularly with an optical path 34 by York 31a and 31b of an electromagnet is impressed.

[0018] By controlling the current of this electromagnet, the direction of the saturation magnetization of Bi permutation rare earth iron garnet crystal 32 is controlled, and an about 0-90-degree adjustable faraday's rotation angle is acquired both ways.

[0019] The parallel plate of a rutile single crystal can be used for the walk-off crystal 12 of drawing 1, and it is easy to use the thing of the thickness which is about 0.75mm for it. Moreover, it is easy to use a thing with a focal distance of about 2mm as a convex lens 13.

[0020] Advance of the light in the optical attenuator by the gestalt of this operation is explained based on drawing 4. First, the case where the joint effectiveness from the input side of 2 heart optical fiber to an output side is about 100% is explained based on drawing 4 (a). Carrying out incidence of the light which carried out outgoing radiation from the fiber of 2 heart optical fiber top to the walk-off crystal 12, by whether you are Tsunemitsu or it is abnormality light, it separates into the optical path of 16a and 17a, and after outgoing radiation makes a travelling

direction parallel, and progresses, respectively. Then, two light was changed into the parallel flux of light by the convex lens, and carried out incidence to adjustable Faraday rotator 14 with it, it was reflected by the total reflection film 15, and when carrying out outgoing radiation, they has received 90-degree Faraday rotation. Next, although two light is changed into convergence light by the convex lens 13, after outgoing radiation, the travelling direction of those light becomes parallel again, advances in accordance with the optical path of 16b and 17b, and carries out incidence to the walk-off crystal 12.

[0021] At this time, the light which was Tsunemitsu passes the walk-off crystal 12 as an abnormality light on an outward trip to because of that of the 90-degree plane-of-polarization rotation received by adjustable Faraday rotator. Moreover, on an outward trip, the light which was abnormality light passes a return trip as Tsunemitsu. Consequently, outgoing radiation of the two light is carried out to the same optical path, and they is combined with the optical fiber of 2 heart optical fiber bottom.

[0022] Next, the case where there is almost no association to an output side from the input side of 2 heart optical fiber is explained based on drawing 4 (b). In this case, by the field of an electromagnet, the direction of magnetization of a Faraday-rotation ingredient and the travelling direction of light become almost perpendicular, and the faraday's rotation angle has become zero mostly. However, in a return trip, again, the optical path of two light is in agreement with drawing 4 (a) until it carries out incidence to the walk-off crystal 12.

[0023] However, in the walk-off crystal 12, the light which the light which was abnormality light on the outward trip was abnormality light also in the return trip, and was Tsunemitsu on the outward trip is Tsunemitsu also in a return trip, and when carrying out outgoing radiation, two light expands separation width of face further, and it carries out incidence to the point which is separated from the core of a lower optical fiber. That is, not almost all light is combined with the optical fiber of an output side.

[0024] So, in order to obtain the predetermined magnitude of attenuation, the current added to an electromagnet is controlled, the direction of the synthetic field of an electromagnet and a permanent magnet is controlled, by this, the include angle between the direction of the saturation magnetization of a Faraday-rotation ingredient and the travelling direction of light is adjusted, and a faraday's rotation angle is adjusted. Therefore, when the current of an electromagnet is zero, the magnitude of attenuation is zero mostly, and the magnitude of attenuation increases it while increasing the current of an electromagnet.

[0025] By the way, what is necessary is to constitute a collimator from a 2 heart optical fiber, a walk-off crystal, and a convex lens, and just to adjust the distance of a convex lens and the total reflection film of adjustable Faraday rotator, and the include angle of the medial axis of a convex lens, and the total reflection film of adjustable Faraday rotator to make after that about assembly.

[0026] (Gestalt 2 of operation) Drawing 2 is the mimetic diagram showing the optical configuration of the optical attenuator by the gestalt 2 of operation of this invention. 21 is the optical fiber of the 2 hearts and, for 22, as for a convex lens and 24, a walk-off crystal and 23 are [adjustable Faraday rotator and 25] total reflection mirrors.

[0027] Here, adjustable Faraday rotator 24 can be constituted by arranging the total reflection mirror 25 between Bi permutation rare earth iron garnet crystal 32 shown in drawing 3 , and a permanent magnet 33.

[0028] About advance actuation of light, it is the same as that of the gestalt 1 of operation. Since it is only the point that adjustable Faraday rotator 24 and the total reflection mirror 25 were separated, that the degree of freedom of optical-path adjustment increases only differ.

[0029] What is necessary is just to use a walk-off crystal, a lens, and one Bi permutation rare earth iron garnet crystal at a time in the two above-mentioned operation gestalten, respectively. Moreover, Bi permutation rare earth iron garnet crystal is good by the thickness of the one half of the conventional example.

[0030] Moreover, in the optical attenuator of this invention, since the optical fiber of I/O is pulled out by one side, it can make the management tooth space of an optical fiber small.

[0031] Furthermore, in the optical attenuator of this invention, in two optical paths separated

according to polarization, since the optical path length is equal, a polarization distribution compensating plate is not needed.

[0032] Therefore, low cost-ization by reduction of components mark is attained in the optical attenuator of this invention. Moreover, since the approach of assembly is as the gestalt 1 of operation having explained, there are few the man days.

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] Drawing showing the optical configuration of the optical attenuator by the gestalt 1 of operation of this invention.

[Drawing 2] Drawing showing the optical configuration of the optical attenuator by the gestalt 2 of operation of this invention.

[Drawing 3] The perspective view showing the principal part of the adjustable Faraday rotator in the optical attenuator by the gestalt 1 of operation of this invention.

[Drawing 4] Drawing showing advance actuation of the light in the optical attenuator by the gestalt 1 of operation of this invention. For drawing 4 (a), drawing and drawing 4 (b) which show the case where the light of the whole quantity joins together between I/O are drawing showing the case where the light of the whole quantity declines.

[Drawing 5] Drawing showing the optical configuration in the conventional optical attenuator.

[Description of Notations]

11 21 2 heart optical fiber

12 22 Walk-off crystal

13 23 Convex lens

14 24 Adjustable Faraday rotator

15 Total Reflection Film

16a, 16b, 17a, 17b, 34 Optical path

18 Optical Fiber of Input

19 Optical Fiber of Output

25 Total Reflection Mirror

31a, 31b York of an electromagnet

32 Bi Permutation Rare Earth Iron Garnet Crystal

33 Permanent Magnet

[Translation done.]

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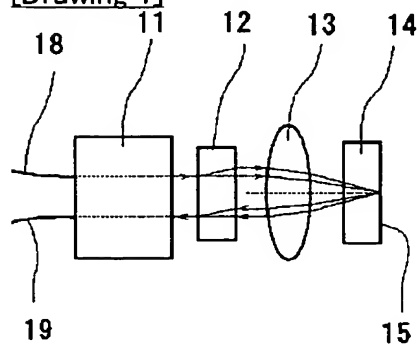
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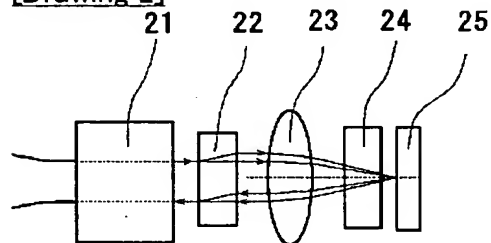
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DRAWINGS

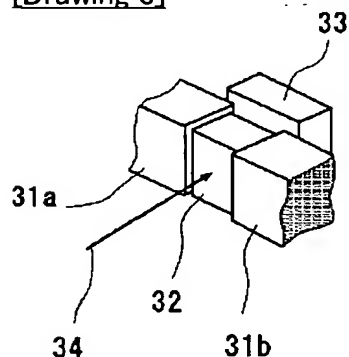
[Drawing 1]



[Drawing 2]

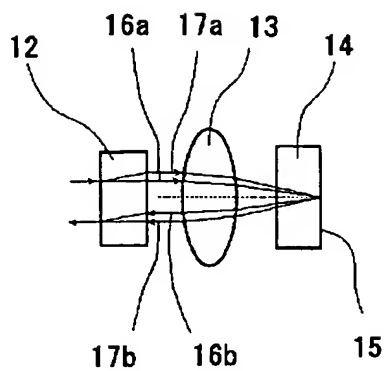


[Drawing 3]

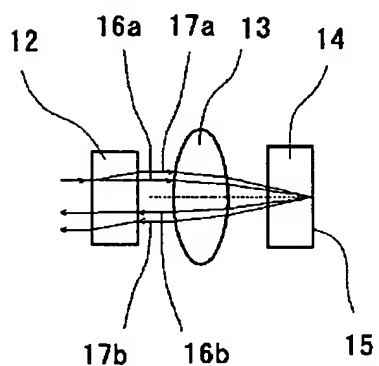


[Drawing 4]

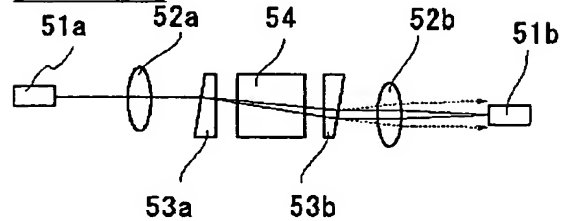
(a)



(b)



[Drawing 5]



[Translation done.]

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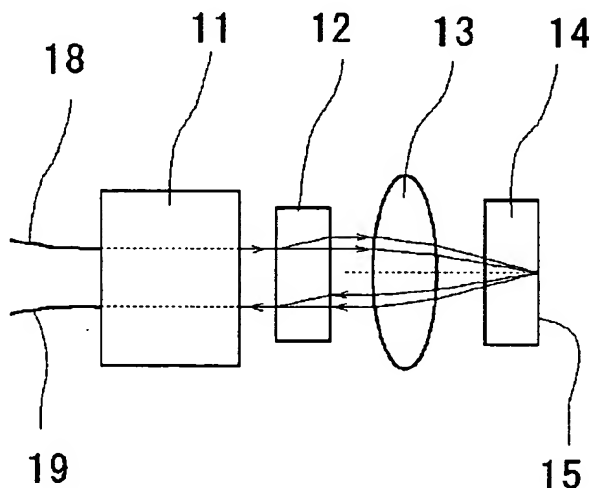
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(54) 【発明の名称】 光アッテネータ

(57) 【要約】

【課題】 部品点数を減少させ、低コストの光アッテネータを提供すること。

【解決手段】 本発明の光アッテネータは、2芯光ファイバと、ウォークオフ結晶と、レンズと、光学面の一方に全反射膜を有する可変ファラデー回転子が、光路方向に、この順に配置されて構成される。また、前記光学面の一方に全反射膜を有する可変ファラデー回転子に替えて、可変ファラデー回転子と全反射鏡を用いることもできる。さらに、前記可変ファラデー回転子は、ファラデー回転材料と電磁石と永久磁石を備えて構成されていてもよい。



【特許請求の範囲】

【請求項1】 2芯光ファイバと、ウォークオフ結晶と、レンズと、光学面的一方に全反射膜を有する可変ファラデー回転子が、光路方向に、この順に配置されて成ることを特徴とする光アッテネータ。

【請求項2】 2芯光ファイバと、ウォークオフ結晶と、レンズと、可変ファラデー回転子と、全反射鏡が、光路方向に、この順に配置されて成ることを特徴とする光アッテネータ。

【請求項3】 前記可変ファラデー回転子は、ファラデー回転材料と電磁石と永久磁石とを備えて構成されることを特徴とする請求項1または2のいずれかに記載の光アッテネータ。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】本発明は、光通信システム等において光強度を減衰して調整する光アッテネータに係り、特に、波長多重光通信装置に用いて好適な、ファラデー回転子を備える可変型の光アッテネータに関する。

【0002】

【従来の技術】電流の制御によって、ファラデー回転角を制御して、光の減衰を行う光アッテネータは、機械的な可動部分を持たないために、信頼性の高い光アッテネータとして動作する。特に、ファラデー回転結晶の磁化を飽和させたまま、磁化方向と光透過方向の間の角度を変化させて、ファラデー回転角を制御するファラデー回転子を用いた光アッテネータは、磁区の変化による光散乱を起こさないで、偏波依存性と過剰損失の少ない減衰器として動作する。

【0003】図5に、従来から用いられている一般的な光アッテネータの構成を示す。光ファイバ51aを出射した光はレンズ52aにより平行光束に変換され、くさび形複屈折結晶53aに入射する。この結晶を通過するとき、光の常光成分と異常光成分は、それぞれの屈折率に応じた屈折を受ける。次に、それぞれの成分の光は可変ファラデー回転子54により、0～90°程度の偏光面の回転を受けた後、くさび形複屈折結晶53bを透過して、レンズ52bにより収束光束に変換されて、一部の光が光ファイバ51bに結合する。

【0004】ここで、くさび形複屈折結晶53aと53bにおけるくさびの向きは逆向きであり、c軸（光学軸）の方向は、ほぼ直交している。従って、可変ファラデー回転子54によるファラデー回転角がほぼ90°のとき、くさび形複屈折結晶53aを常光として通過した光は、くさび形複屈折結晶53bを同じく常光として通過する。その結果、くさび形複屈折結晶53aと53bで受ける光の進行方向の変化は打ち消し合い、すべての常光成分は光ファイバ51bに結合する。また、くさび形複屈折結晶53aを異常光として通過する光に対して

【0005】それに対して、ファラデー回転角が0°のときには、くさび形複屈折結晶53a、53bの一方を常光として通過する光は、他方を異常光として通過するために、2つのくさび形複屈折結晶を通過するときの進行方向の変化は打ち消し合わない。その結果、光は光ファイバ51bに結合しない。

【0006】従って、ファラデー回転角が90°のとき、減衰量はゼロであり、ファラデー回転角が0°に近づくにつれて、減衰量が増大する。

【0007】

【発明が解決しようとする課題】従来例として説明した光アッテネータにおいては、2枚のくさび形複屈折結晶を用いている。また、光アッテネータの多くの用途においては偏波分散をゼロにする必要があり、そのときには、もう1枚の複屈折結晶である偏波分散補償板が必要となる。

【0008】一般に複屈折結晶素子やレンズの製作コストは、容易には低減できない。それゆえ、多数の複屈折結晶素子やレンズの使用は、光アッテネータの製作コストを引き上げる。

【0009】そこで、本発明は、部品点数を減少させ、低コストの光アッテネータを提供することを課題とする。

【0010】

【課題を解決するための手段】上記目的を達成するために、本発明の光アッテネータにおいては、ウォークオフ結晶とレンズと可変ファラデー回転子に光を往復で透過させることにより、部品点数を減少させている。

【0011】即ち、本発明の光アッテネータは、2芯光ファイバと、ウォークオフ結晶と、レンズと、光学面的一方に全反射膜を有する可変ファラデー回転子が、光路方向に、この順に配置されて構成される。

【0012】また、本発明の光アッテネータは、2芯光ファイバと、ウォークオフ結晶と、レンズと、可変ファラデー回転子と、全反射鏡を備えて構成することもできる。

【0013】さらに、前記可変ファラデー回転子は、ファラデー回転材料と電磁石と永久磁石を備えて構成されていてもよい。

【0014】

【発明の実施の形態】次に、本発明の実施の形態について、図1～図4に基づいて説明する。

【0015】（実施の形態1）図1は、本発明の実施の形態1による光アッテネータの光学的構成を示す模式図である。11は2芯の光ファイバであり、入力的光ファイバ18と出力的光ファイバ19を一体化したものである。12はウォークオフ結晶であり、13は凸レンズ、14は可変ファラデー回転子であり、この光学面的一方に全反射膜15が形成されている。

【0016】ここで、用いられる可変ファラデー回転子

14 について、図3に基づいて説明する。図3において、32はBi置換希土類鉄ガーネット結晶であり、31aと31bは電磁石のヨークであり、33は永久磁石である。光は光路34に沿って進み、永久磁石33の側の光学面に形成された全反射膜によって反射され、光路34を逆行する。

【0017】また、Bi置換希土類鉄ガーネット結晶32の寸法は $0.8 \times 0.8 \times 0.4$ mmであり、永久磁石33により、光路34の方向の固定磁界が印加され、電磁石のヨーク31aと31bによって、光路34に直交する可変の磁界が印加される。

【0018】この電磁石の電流を制御することにより、Bi置換希土類鉄ガーネット結晶32の飽和磁化の方向を制御し、往復で $0 \sim 90^\circ$ 程度の可変のファラデー回転角を得る。

【0019】図1のウォークオフ結晶12には、ルチル単結晶の平行平板を用いることができ、 0.75 mm程度の厚さのものが使い易い。また、凸レンズ13としては焦点距離2 mm程度のものが使い易い。

【0020】本実施の形態による光アッテネータにおける光の進行について、図4に基づいて説明する。まず、2芯光ファイバの入力側から出力側への結合効率がほぼ100%の場合について、図4(a)を基に説明する。2芯光ファイバの上側のファイバから出射した光は、ウォークオフ結晶12に入射し、常光であるか、異常光であるかによって、それぞれ、16aと17aの光路に分離して、出射後は進行方向を平行にして進む。その後、2つの光は、凸レンズによって、平行光束に変換され、可変ファラデー回転子14に入射し、全反射膜15で反射され、出射するときには、 90° のファラデー回転を受けている。次に、2つの光は凸レンズ13により、収束光に変換されるが、それらの光の進行方向は、出射後、再び、平行になり、16bと17bの光路に沿って進行し、ウォークオフ結晶12に入射する。

【0021】このとき、往路では常光であった光は、可変ファラデー回転子で受けた 90° の偏光面回転のゆえに、異常光としてウォークオフ結晶12を通過する。また、往路では異常光であった光は、常光として、復路を通過する。その結果、2つの光は、同一の光路に出射し、2芯光ファイバの下側の光ファイバに結合する。

【0022】次に、2芯光ファイバの入力側から出力側への結合がほとんどない場合について、図4(b)を基に説明する。この場合、電磁石の磁界により、ファラデー回転材料の磁化の方向と光の進行方向は、ほぼ垂直になり、ファラデー回転角は、ほぼゼロになっている。しかし、復路において、再び、ウォークオフ結晶12に入射するまでは、2つの光の光路は、図4(a)と一致している。

【0023】ところが、ウォークオフ結晶12において、往路で異常光であった光は、復路においても、異常

光であり、また、往路で常光であった光は、復路においても、常光であり、出射するときには、2つの光は、さらに分離幅を広げて、下側の光ファイバのコアから離れた点に入射する。即ち、ほとんどの光は、出力側の光ファイバに結合しない。

【0024】そこで、所定の減衰量を得るためには、電磁石に加える電流を制御し、電磁石と永久磁石の合成磁界の方向を制御し、これによって、ファラデー回転材料の飽和磁化の方向と光の進行方向との間の角度を調整して、ファラデー回転角を調整する。従って、電磁石の電流がゼロのとき、減衰量は、ほぼゼロであり、電磁石の電流を増すとともに、減衰量が増加する。

【0025】ところで、組立については、2芯光ファイバとウォークオフ結晶と凸レンズでコリメータを構成し、その後、凸レンズと可変ファラデー回転子の全反射膜との距離、および、凸レンズの中心軸と可変ファラデー回転子の全反射膜とのなす角度を調整すればよい。

【0026】(実施の形態2) 図2は本発明の実施の形態2による光アッテネータの光学的構成を示す模式図である。21は2芯の光ファイバであり、22はウォークオフ結晶、23は凸レンズ、24は可変ファラデー回転子、25は全反射鏡である。

【0027】ここで、可変ファラデー回転子24は、図3に示した、Bi置換希土類鉄ガーネット結晶32と永久磁石33の間に全反射鏡25を配置することによって構成できる。

【0028】光の進行動作については、実施の形態1と同様である。異なるのは、可変ファラデー回転子24と全反射鏡25が分離された点だけなので、光路調整の自由度が増えることだけである。

【0029】上記の2つの実施形態においては、ウォークオフ結晶、レンズ、および、Bi置換希土類鉄ガーネット結晶を、それぞれ、1枚ずつ使えばよい。また、Bi置換希土類鉄ガーネット結晶は、従来例の半分の厚さでよい。

【0030】また、本発明の光アッテネータにおいては、入出力の光ファイバが、片側に引き出されているので、光ファイバの取り回しスペースを小さくすることができる。

【0031】さらに、本発明の光アッテネータにおいては、偏光に応じて分離した2つの光路において、光路長が等しいので、偏波分散補償板を必要としない。

【0032】従って、本発明の光アッテネータにおいては、部品点数の減少による低コスト化が可能になる。また、組立の方法は実施の形態1で説明したとおりなので、その工数は少ない。

【0033】

【発明の効果】以上説明したように、本発明によれば、部品点数が少なく、小型で、低コストの光アッテネータを提供することが可能になる。

【図面の簡単な説明】

【図1】本発明の実施の形態1による光アッテネータの光学的な構成を示す図。

【図2】本発明の実施の形態2による光アッテネータの光学的な構成を示す図。

【図3】本発明の実施の形態1による光アッテネータにおける可変ファラデー回転子の主要部を示す斜視図。

【図4】本発明の実施の形態1による光アッテネータにおける光の進行動作を示す図。図4(a)は、入出力の間で全量の光が結合する場合を示す図、図4(b)は全

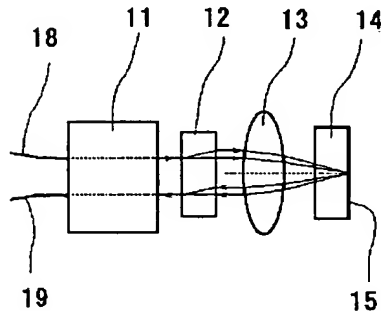
量の光が減衰する場合を示す図。

【図5】従来の光アッテネータにおける光学的な構成を示す図。

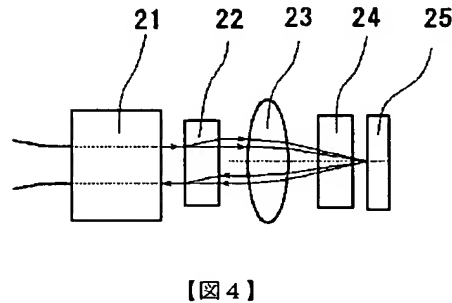
【符号の説明】

- 11, 21 2芯光ファイバ
12, 22 ウォークオフ結晶
13, 23 凸レンズ
14, 24 可変ファラデー回転子
15 全反射膜
16a, 16b, 17a, 17b, 34 光路
18 入力の光ファイバ
19 出力の光ファイバ
25 全反射鏡
31a, 31b 電磁石のヨーク
32 Bi置換希土類鉄ガーネット結晶
33 永久磁石

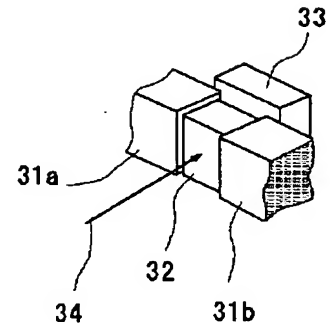
【図1】



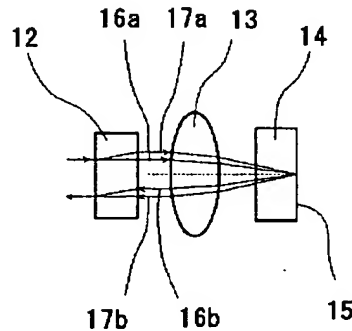
【図2】



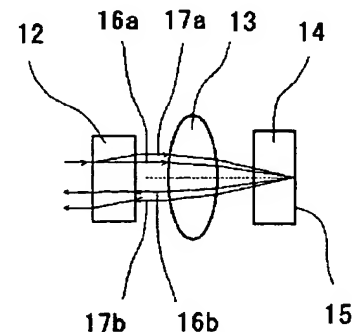
【図3】



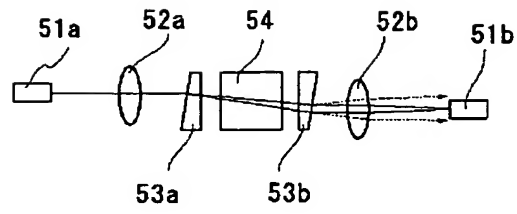
(a)



(b)



【図 5】



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